(12) UK Patent Application (19) GB (11) 2 099 978 A

(21) Application No 8210340
(22) Date of filing 7 Apr 1982
(30) Priority data
(31) 8114375
(32) 9 May 1981
(33) United Kingdom (GB)
(43) Application published 15 Dec 1982
(51) INT CL[3] F23R 3/06
(52) Domestic classification F4T 101 AD
(56) Documents cited
GB 1575410
GB 1563124
GB 1347697
GB 0953060
GB 0836117
GB 0739093
(58) Field of search F4T

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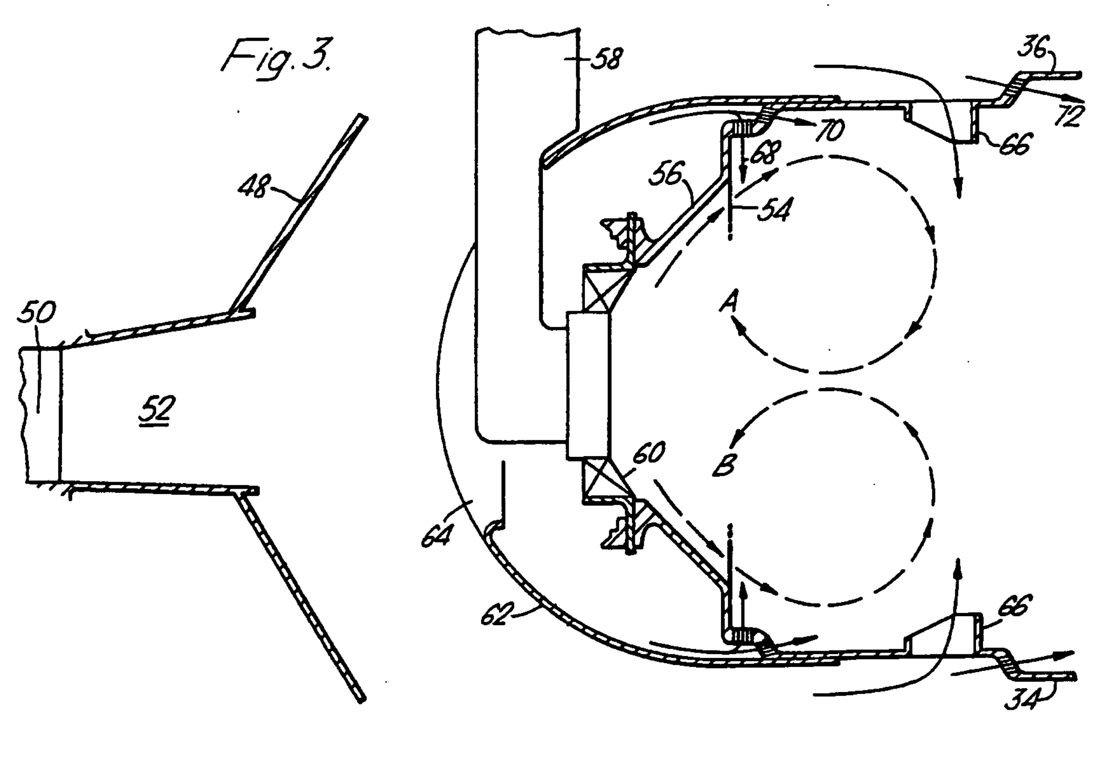
(54) Gas turbine engine combustor

(57) In a gas turbine engine the emissions of unburnt hydrocarbons and carbon monoxide produced at low power conditions are controlled by an arrangement which improves the combustion efficiency. The arrangement may also aid in the reduction of NOx emissions at high power conditions, as the air fuel ratio can be richer without affecting the levels of the other emissions, including smoke, to any substantial degree.

The arrangement comprises an annular combustion chamber having a number of wide-angle pots (56), each of which has an air-spray type fuel injector (58) and a curved vane swirler (60). The wide angle pots cause a strong toroidal vortex (A, B) which substantially occupies the whole of the primary zone of the combustion chamber and the curved vane swirlers maintains the flow in contact with the pots. Any fuel which tends to migrate into the wall cooling flows (70, 72) is urged back into the vortex flow by air flowing across the end wall through inlets (68).

Substantially the whole of the interior surface of the primary zone is washed by a flow of air to prevent carbon accretion and the surface area to be cooled is kept to a minimum.

Fig. 3.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig. 1.

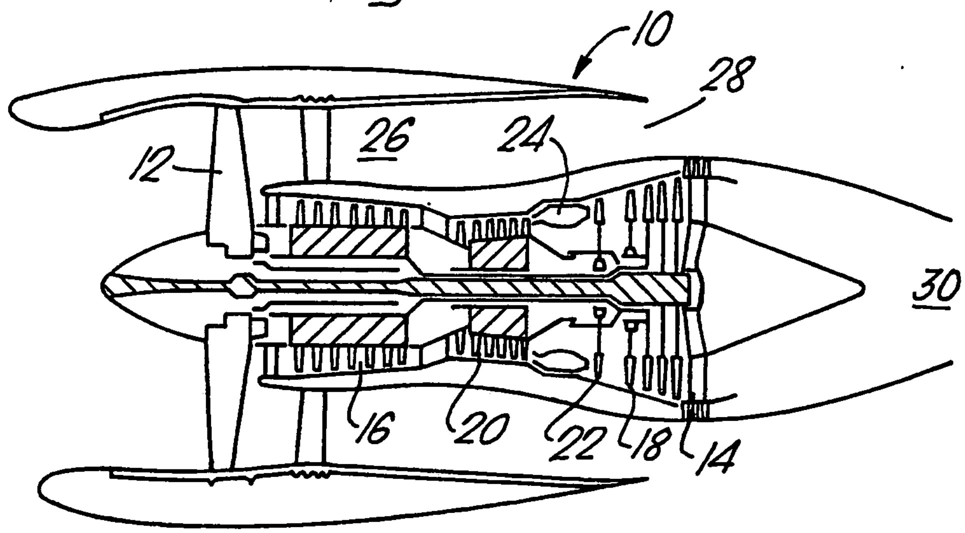
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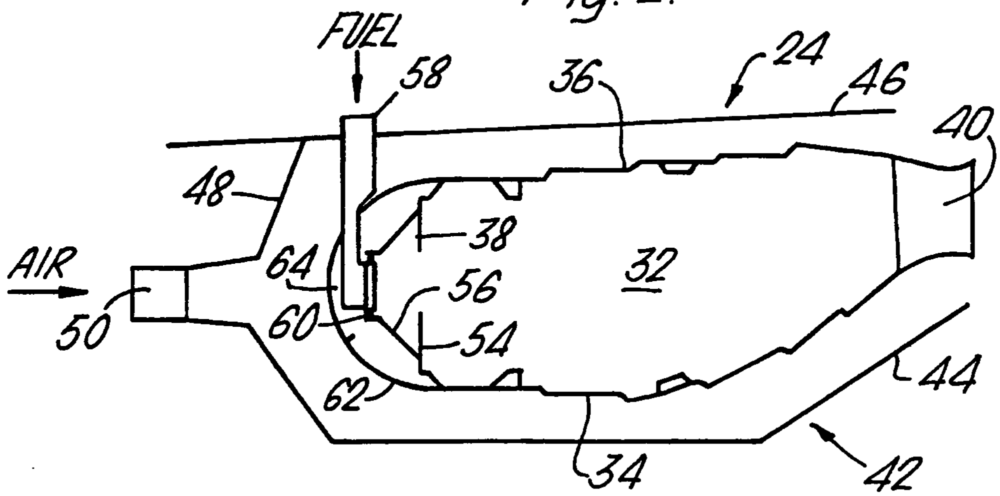
Fig. 2.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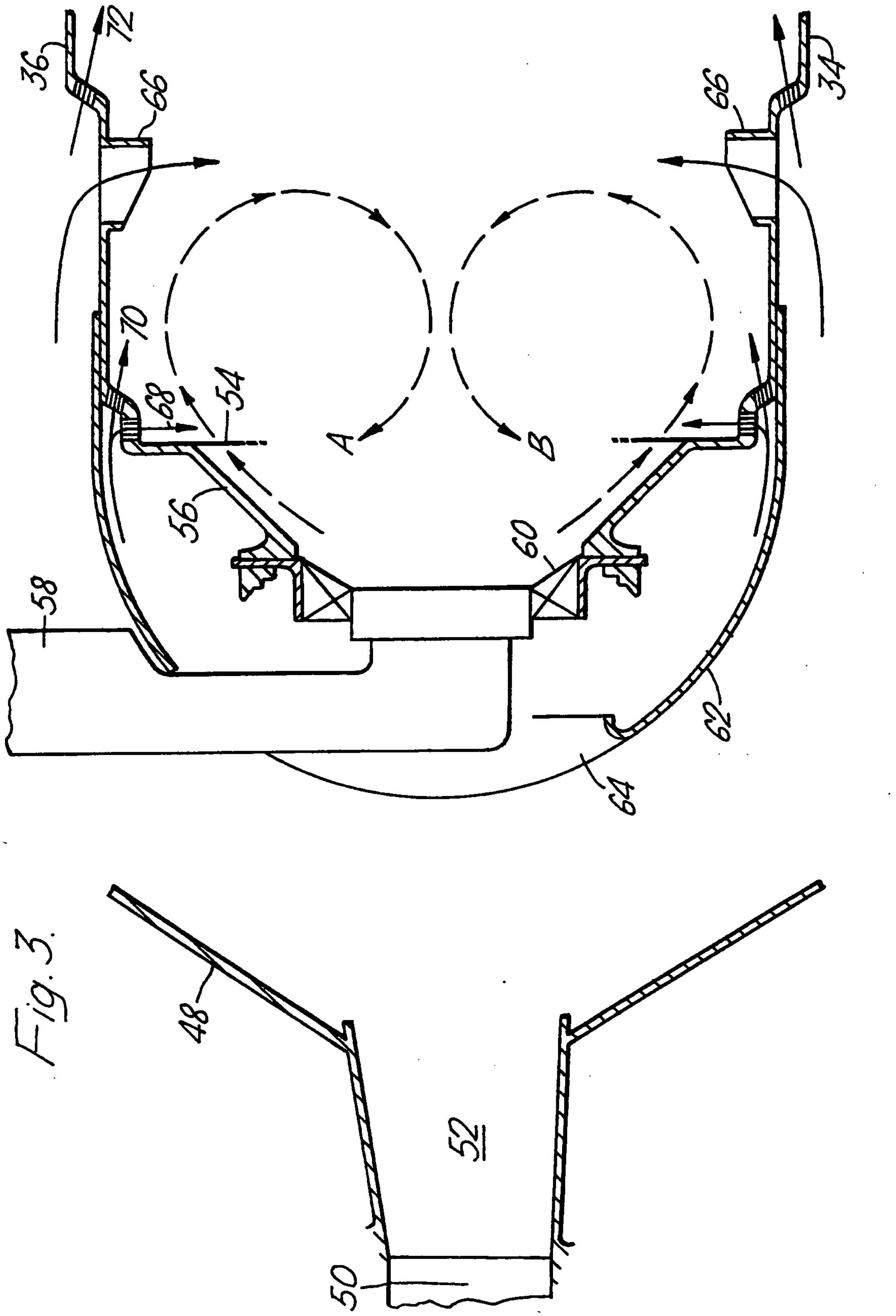
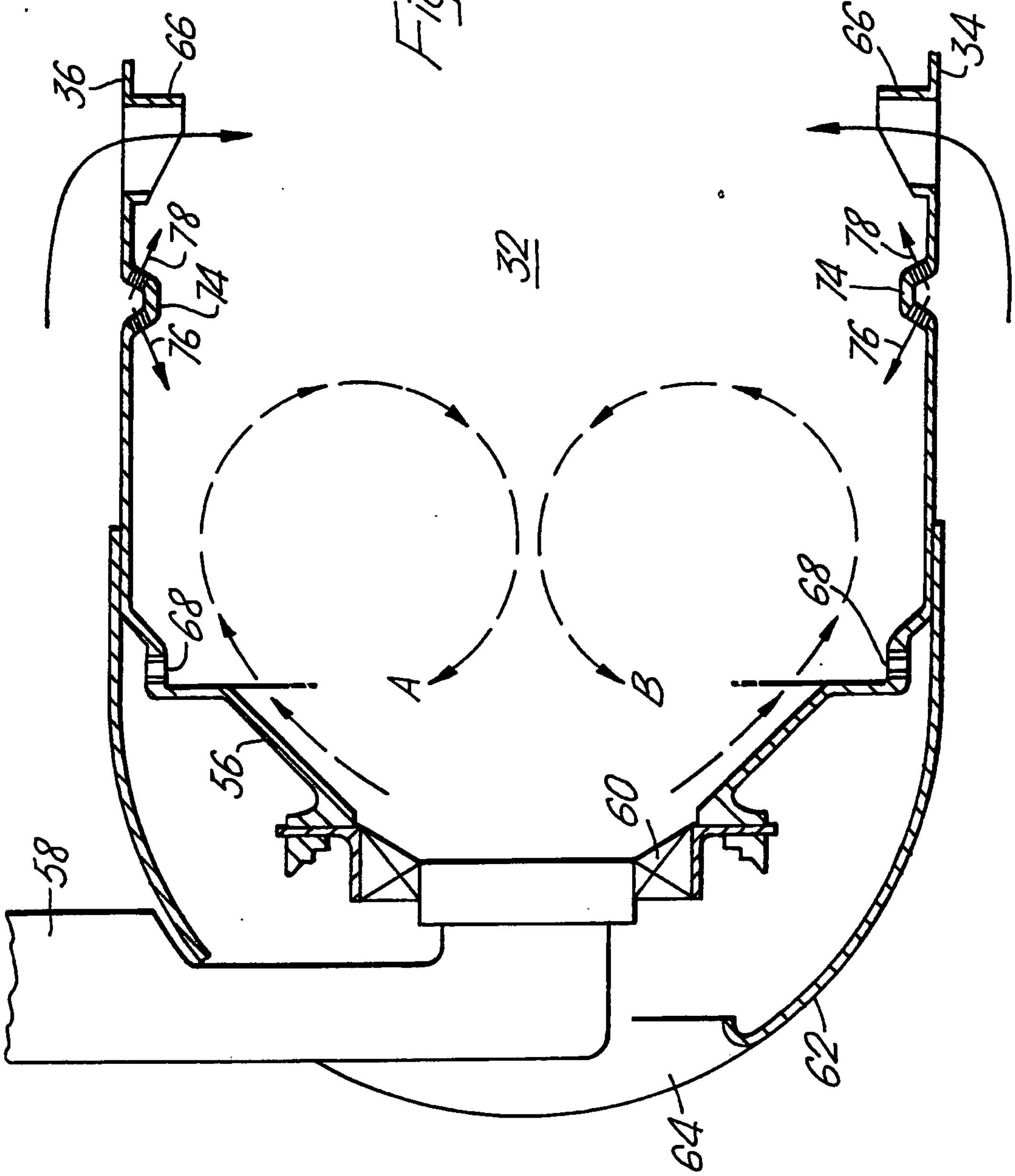


Fig. 3.

Fig. 4.



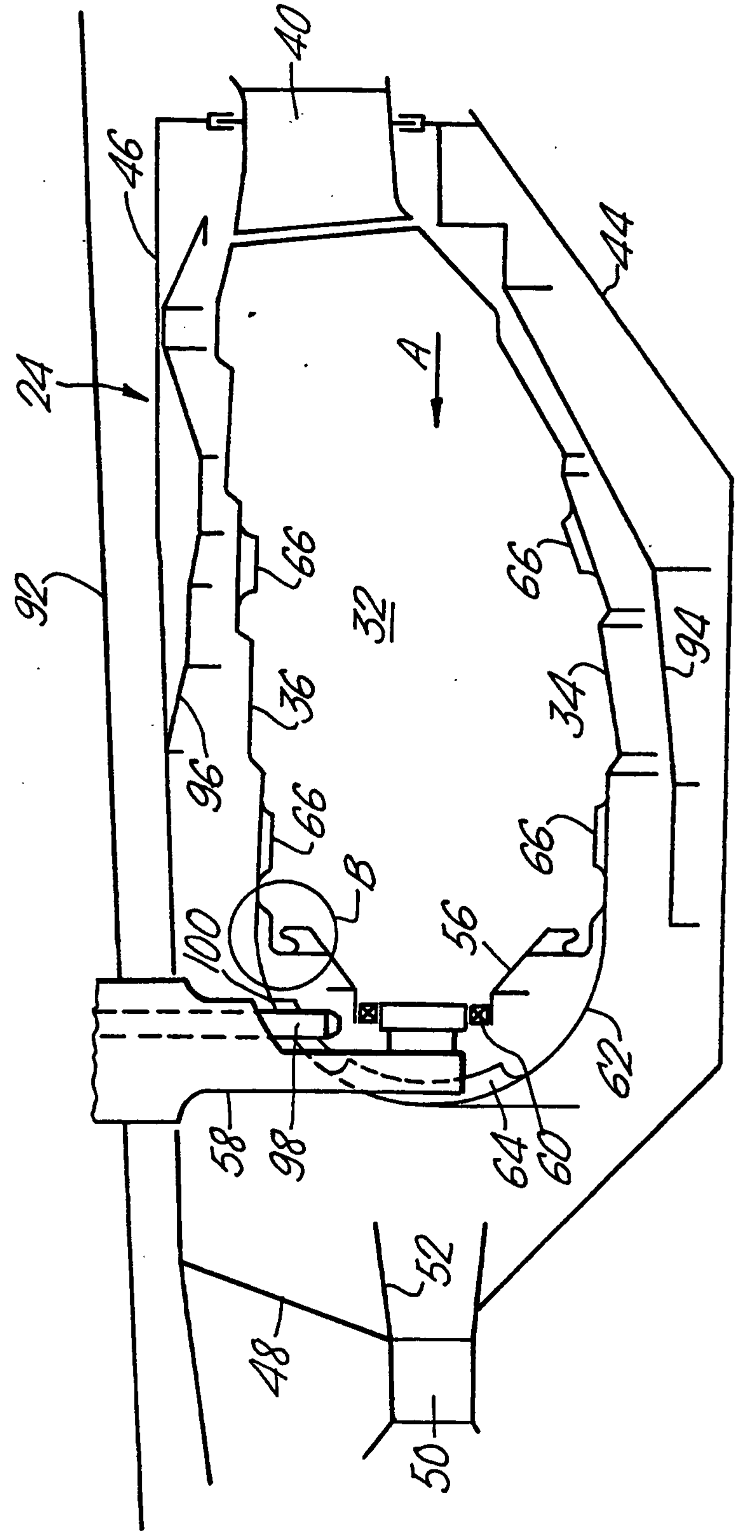

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Fig.5.

Fig. 6.

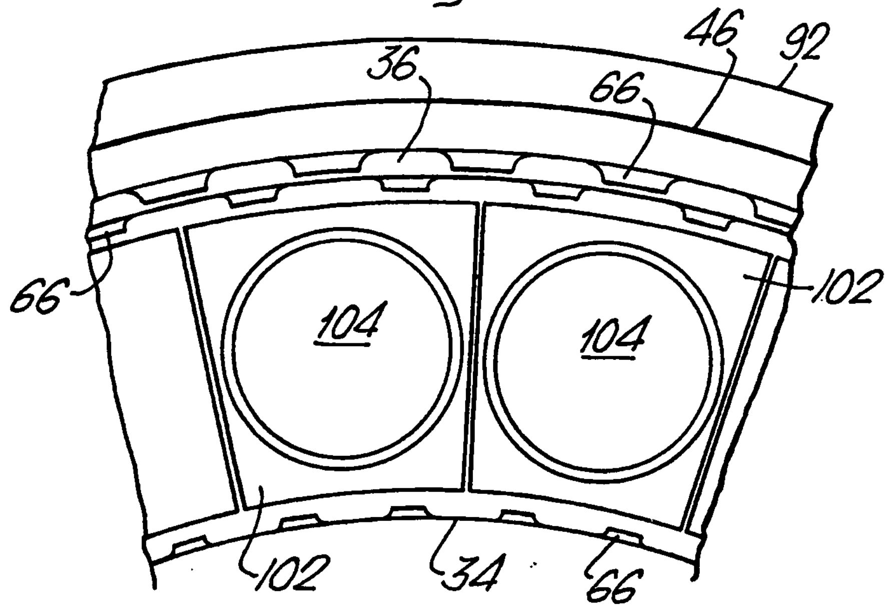


Fig. 7.

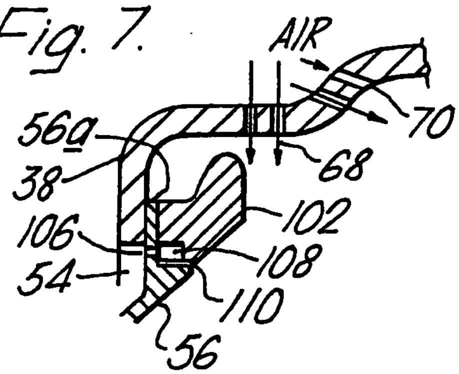


Fig. 9.

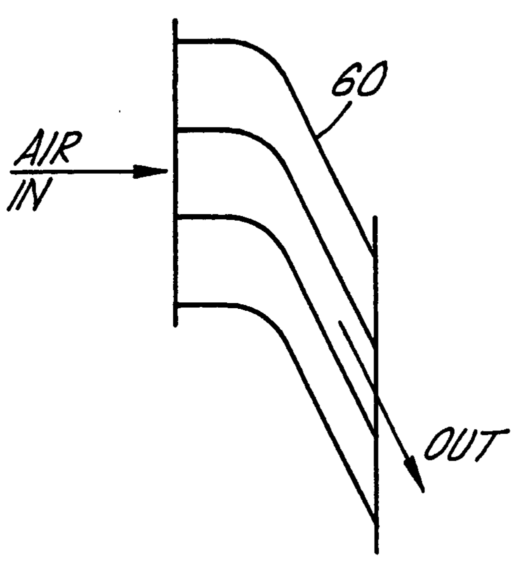
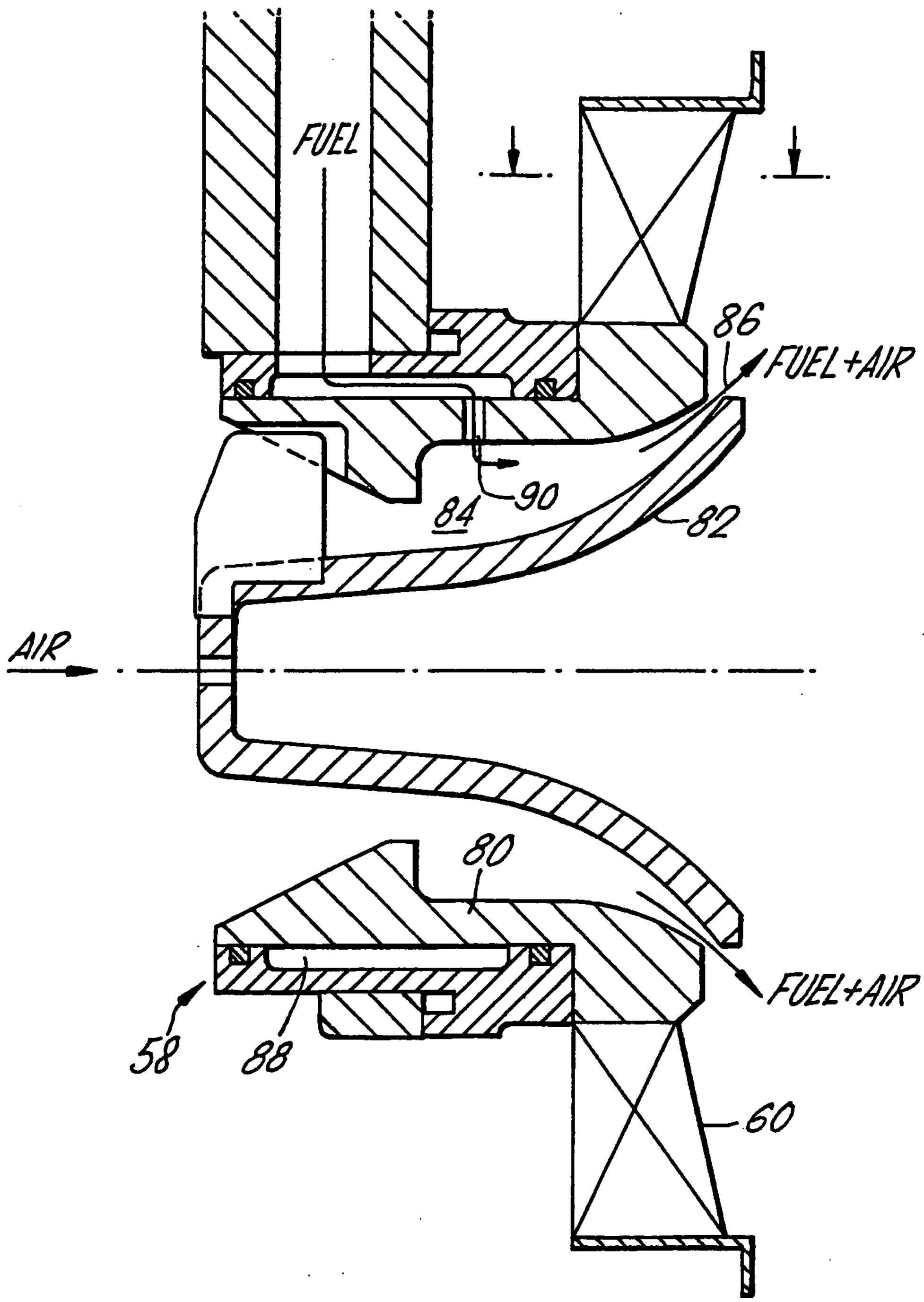


Fig. 8.



SPECIFICATION

Gas turbine engine combustor

This invention relates to annular type combustors for gas turbine engines, and is concerned with providing an annular combustor for reducing undesirable engine emissions.

The introduction of legislation concerning environmental pollution particularly in the USA, has meant that much effort has been expended by gas turbine designers to reduce the undesirable emissions from gas turbine engines. These emissions are in the form of partially burnt fuel and carbon monoxide which are usually produced at low engine power conditions, and oxides of nitrogen and smoke which are usually produced at high engine power conditions. The control of all these emissions by a single design of combustor has proved to be very difficult, even using combustors having a multi-stage fuel injector system. This is because the solution of the problem at low power tends to exacerbate the problem at high power and vice-versa.

The present invention seeks to provide a combustor in which the emissions occurring at low power and the smoke which occurs at high power are fully controlled, whilst the emission of oxides of nitrogen are at least under partial control. In order to achieve these objectives, the combustor of the present invention relies on close control of the aerodynamic and thermodynamic processes which take place within the primary zone of the combustor.

The present invention provides an annular combustion chamber for a gas turbine engine, the combustion chamber including an annular portion defined by inner and outer annular walls and an upstream end wall, the inner and outer walls having a plurality of apertures to allow air to flow into the annular portion, the upstream wall having a plurality of equi-spaced apertures therein, a conically shaped open-ended pot being attached to the upstream wall, co-axial with each aperture in the end wall, the included angle of each pot being in the range 30° to 90°, a fuel injector and a swirler being located in the upstream end of each pot, the air swirler being located between the fuel injector and the wall of the pot, each air swirler having a plurality of curved vanes capable of turning a flow air through an angle of up to 65°, at least some of the apertures in the inner and outer walls being aligned to direct a flow of air across the downstream face of the upstream end wall.

The present invention will now be more particularly described with reference to the accompanying drawings in which:

Figure 1 shows a gas turbine engine which incorporates an annular combustion chamber according to the present invention,

Figure 2 illustrates diagrammatically, to a larger scale, the combustion chamber shown in Figure 1,

Figure 3 shows the upstream end of the combustion chamber in Figure 2 to a larger scale,

Figure 4 shows the upstream end of a further form of combustion chamber according to the present invention,

Figure 5 illustrates diagramatically another form of combustion chamber according to the present invention,

Figure 6 is a view on arrow A in Figure 5, and

Figure 7 is a view detail B in Figure 5.

Figure 8 shows an airspray type fuel injector suitable for use with the combustion chambers shown in Figures 3, 4 and 5 to 7, and

Figure 9 is a section on line 9-9 in Figure 8.

Refering to Figure 1, a gas turbine engine 10 comprises a single stage fan 12 driven by a turbine 12, an intermediate pressure compressor 16 driven by an intermediate pressure turbine 18, a high pressure compressor 20 driven by a high pressure turbine 22, and combustion apparatus 24.

The air propelled by the fan 12 flows through a bypass duct 26 and exhausts through a propulsion nozzle 28 and the gases from the turbines 14, 18 and 22 exhaust through a propulsion nozzle 30.

Referring more particularly to Figure 2, the combustion apparatus 24 comprises an annular combustion chamber 32 defined by inner and outer annular walls 34, 36 respectively, an upstream end wall 38, a plurality of nozzle guide vanes 40 being located at the downstream end of the chamber. The combustion chamber is itself contained within an annular housing 42 having inner and outer walls 44, 46 respectively and an upstream end wall 48. The annular housing 42 receives a flow of compressed air from the high pressure compressor 20 *via* a row of outlet guide vanes 50 and a dump diffuser 52.

The upstream wall 38 has a plurality of circumferentially arranged equi-spaced apertures 54 and attached to the upstream wall on the centre-line of each aperture is a pot 56, having an included angle of typically 90° facing downstream. A fuel injector 58 is located at the upstream end of each pot and an air swirler 60 is positioned between the fuel injector and the pot.

A semi-toroidal housing 62 encloses the upstream end of the combustion chamber 32 and has a plurality of openings 64 to allow air to flow into both the primary zone of the combustion chamber and into the fuel injector, and to allow each fuel injector to be inserted in its respective pot.

Each fuel injector is preferably of the air spray type, that it is to say an injector in which a high velocity, high pressure flow of air impacts upon a flow of fuel which is either in sheet form or individual jets, to cause atomisation of the fuel.

Referring to Figure 3, the air swirler 60 comprises a row of curved vanes which are capable of turning the airflow through angle of 65° or thereabouts.

The inner and outer walls 34, 36 have chutes 66 for the inflow of dilution air, and inlets 68, 70 and 72 for the inflow of air mainly for cooling the walls of the combustion chamber. Typically, the inlets 68, 70 and 72 comprise a number of closely spaced holes drilled at a particular angle to ensure that the cooling air flows in the required direction. The flow through inlets 68 apart from performing a cooling function on the upstream wall 38 also has a flow controlling function, as described below.

The individual features of the arrangement are

designed and inter-related to produce the following effects; a strong double vortex which substantially occupies the whole primary zone volume, i.e. the volume upstream of the chutes 66, a means of preventing any fuel from being entrained in the wall cooling flow, substantially all metal surfaces washed by a flow of fast moving air to prevent carbon accretion and minimising the surface areas to be cooled.

The strong double vortex is provided by the wide angle pots 56 and the flow is maintained in attachment to the pot by the swirlers 60 which are capable of turning the air flow through angles of 60° or more. The inwardly directed flow of air through inlets 68, which is normal to the longitudinal axis of the combustor prevents any fuel in the double vortex from becoming detached from this flow and becoming entrained in the flows of cooling air adjacent the walls 34, 46 of the combustor.

Of the surfaces of the combustor, the interior of the pots are washed by the swirling flow of air from the swirlers 60, the end wall 38 is washed by the air flowing in through inlets 68 and the walls 34, 36 are washed by air flowing in through the inlets 70, 72.

The use of pots 56 of wide angle as well as providing the desired strong double vortex flow also has the added benefit of reducing the surface area which requires cooling.

In operation, fuel is supplied to the fuel injector 58 and air flows through the fuel injector, the swirl vanes 60 and the air inlets 66, 68, 70 and 72. A very vigorous toroidal vortex flow, as indicated by arrows A and B is set up in the primary zone of the combustion chamber due to the wide angle pots 56 and the swirlers 60. There is a very rapid mixing of fuel and air even at low power conditions, when because of the relatively low pressure and velocity of the air through the fuel injector, the atomising effect of this airflow is reduced. Any fuel which tends to flow out of the main vortex flow into the wall cooling flow is captured by the air flow through inlets 68 and held in the vortex flow. Thus, substantially the whole of the fuel takes part in the combustion process, particularly at low power, thereby reducing the emissions of unburnt hydrocarbons and carbon monoxide at this power condition.

The aerodynamic and thermodynamic conditions created in the primary zone of the combustion chamber also allows the air fuel ratio in the primary zone to be richer both at low and high power condition. At low power, the richer air fuel ratio can be tolerated because of the improvement in combustion efficiency and at high power, the richer air fuel ratio tends to reduce NOx emissions, althoug there may be an increase in smoke levels, but not to an unacceptable level.

Referring to Figure 4, the combustion chamber 32 has a V-type cooling ring 74 in each wall 34, 36 and each cooling ring has an upstream facing air inlet 76 and a downstream facing inlet 78. The air flowing through these inlets is for cooling the walls of the combustion chamber, but the air flowing through the inlets 76 is also used to re-inforce the flow through inlets 68, to prevent fuel from becoming entrained with the cooling air flow.

Any fuel which does become mixed with the cooling flow is difficult to burn because the air fuel ratio is weak and the temperature is low.

Figure 8 shows an airspray fuel injector 58 comprising a body 80 and a pintle 82 which between them define a venturi duct 84 terminating in a control gap 86. The injector is mounted centrally of the ring of swirler vanes 60 and has a fuel manifold 88 with angled fuel inlets 90 into the duct 84.

The swirler vanes preferably comprise a series of curved vanes, as opposed to the more typical angled straight vane which tend to stall and only run partially full of air when turning the air through large angles, e.g. greater than 45°. As shown in Figure 9 vanes of the swirler are arranged to turn the air through angles of up to 65° and may each have a inlet section aligned with the incoming air and which blends in with the remainder of the vane set at the desired outlet angle. Preferably the outlet passages formed between the vanes 60 are relatively long to ensure that the air leaving the swirler leaves at the desired angle, rather than an angle which is less than that desired.

Referring to Figures 5, 6 and 7 in which similar components have been given the same references as in previous figures, the whole length of combustion apparatus 24 is shown within an engine casing 92. Two annulus fillers 94, 96 are located between the inner wall 34 of the combustion chamber and the inner wall 44 of the annular housing, and the outer wall 36 of the combustion and the outer wall 46 of the annular housing, respectively. These fillers serve to control the velocity of the air flowing between them and the combustion chamber walls.

The upstream end of the combustion chamber is located by means of a series of spigots 98, each of which is carried by the respective fuel injector 58, and engages in an aperture in a plate 100 attached to the housing 62.

Figures 6 and 7 in particular, show the attachment of the pots 56 to the wall 38, and an annular heat shield which consists of a number of abutting segments 102 each having a circular opening 104 which correspond with the downstream diameter of the respective pot 56.

The heat shield segments are provided with cooling air through openings 106 in flange 56*a* of each pot. The cooling air flows into a space 108 formed between the heat shield segment and the flange 56*a* and flows out through an annular gap 110 between the segment and the pot.

Whilst it is preferable that the included angle of each pot 56 is 90° thereabouts to create a strong flow reversal in the combustor primary zone and to reduce the area of the upstream wall 38, it may be necessary to reduce this angle in order to keep the flow attached to the pot under all conditions. Component life can be increased in this way at the expense of increasing the surface area to be cooled which would require a greater flow of cooling air.

CLAIMS

1. An annular combustion chamber for a gas turbine engine, the combustion chamber including

an annular portion defined by inner and outer walls and an upstream end wall, the inner and outer walls having a plurality of apertures to allow air to flow into the annular portion, the upstream wall having a plurality of equi-spaced apertures therein, a conically shaped open-ended pot being attached to the upstream wall co-axial with each said aperture in the end wall, the included angle of each pot being in the range 30° to 90°, a fuel injector and a swirler being located in the upstream end of each pot, the air swirler being located between the fuel injector and the wall of the pot, each air swirler having a plurality of curved vanes capable of turning air through an angle of up to 65°, at least some of the apertures in the inner and outer walls being aligned to direct a flow of air across the downstream face of the upstream end wall.

2. An annular combustion chamber as claimed in claim 1 in which the fuel injector comprises an air spray burner having an annular venturi duct terminating in a control gap for the injection of a fuel and air mixture into the primary zone of the combustion chamber.

3. An annular combustion chamber as claimed in claim 1 in which some of the apertures in the annular walls direct a flow of air along the walls in the upstream direction to reinforce the flow of air across the downstream face of the upstream end wall.

4. An annular combustion chamber as claimed in claim 1 in which the upstream end wall of the combustion chamber has an annular heat shield comprising a plurality of adjacent segments attached to the end wall and having circular openings corresponding to the downstream diameter of the conical pots.

5. An annular combustion chamber as claimed in claim 4 in which each heat shield segment is provided with a flow of cooling air through an annular gap between the segment and the respective pot.

6. An annular combustion chamber as claimed in claim 1 in which the combustion chamber is contained within an annular air casing and control walls are provided between the walls of the air casing and the combustion chamber to control the velocity of the air flowing between the control walls and the combustion chamber.

7. An annular combustion chamber as claimed in claim 1 in which the upstream end of the combustion chamber is located by means of a spigot supported by each fuel injector and engaging in a respective opening on a portion of the combustion chamber upstream of the end wall.

8. An annular combustion chamber for a gas turbine engine constructed and arranged for use and operation substantially as herein described, and with reference to the accompanying drawings.

9. A gas turbine engine including an annular combustion chamber as claimed in any one of the preceding claims in which the air supply to the combustion chamber flows *via* a dump diffuser, from the high pressure compressor of the engine.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1982.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.